2001 IGS Activities in the Area of the Ionosphere

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Introduction

The IGS Ionosphere Working Group (Iono_WG) is active since June 1998. The working group's most important short-term goal is the routine provision of global ionosphere Total Electron Content (TEC) maps plus differential code biases (DCBs) with a delay of some days. In the year 2001, to which this Technical Report is dedicated to, the delivery of DCBs was restricted only to those of the GPS satellites. At the time when this Technical Report was written in August 2002, the routine delivery of station DCBs was implemented too.

In the medium- and long-term, the working group intends to develop more sophisticated algorithms for deducing mappings of ionospheric parameters from GPS measurements and to realize near-real-time availability of IGS ionosphere products. The final target is the establishment of an independent IGS ionosphere model.

Five Ionosphere Associate Analysis Centers (IAACs) contribute with their products to the Iono_WG activities:

+ CODE	Center for Orbit Determination in Europe, Astronomical Institute, University of Berne, Switzerland.
+ ESOC	European Space Operations Centre of ESA, Darmstadt, Germany.
+ JPL	Jet Propulsion Laboratory, Pasadena, California, U.S.A.
+ NRCan	Natural Resources Canada, Ottawa, Ontario, Canada.
+ UPC	Polytechnical University of Catalonia, Barcelona, Spain.

It is the intent of this Technical Report to give an overview over the Iono_WG activities in 2001.

Routine Activities

Daily Ionospheric Total Electron Content (TEC) Information

Each IAAC delivers per 24 hours an IONEX file (Schaer et al., 1997) with 12 TEC maps containing global TEC information with a 2-hours time resolution and a daily set of GPS satellite DCBs in its header (the ground station receivers DCBs were included in July 2002).

Weekly Comparisons

On Wednesday of each week the TEC maps from the different IAACs are compared for all days of the week before. These comparisons are done at the IGS Ionosphere Associate Combination Center (IACC) at ESOC. A weekly comparison summary is e-mailed to the "Iono_WG members" via IONO-WG mail.

Furthermore, the daily summaries, the daily IONEX files with the "mean" TEC maps & GPS satellite DCBs and daily TEC & DCB difference files with respect to the "mean" for each IAAC, and also plots of these maps, are made available to the "Iono_WG members" on ESOC's FTP account, ftp anonymous@nng.esoc.esa.de .

The IAACs use very different approaches to establish their TEC maps, resulting in very different temporal and spatial resolutions, and the RMS maps provided in the IAACs IONEX files represent only the internal accuracy of the respective approach. These circumstances reflected strongly in the comparison results, and it became clear quite soon, that the old comparison scheme (Feltens 2000a, Appendix B and Feltens 2000c, Appendix B) had to be improved. The Iono_WG thus decided to upgrade the comparison/combination algorithm with a geographic-dependent weighting, whereby the individual IAACs-weights are derived from external validations with self-consistency tests (Feltens 2000a, Appendix A and Feltens 2000c, Appendix A). The weekly comparisons are done with this new approach since August 2001. The external validations needed for this method are made routinely by the Ionosphere Associate Validation Centers (IAVCs) UPC and NRCan prior to the weekly comparisons at the IACC at ESOC. The transition from the old approach to the new one with the weights derived from external validations was done with an overlap time of four weeks from 19 August 2001 until 15 September 2001, i.e. during that time the comparisons were run with both methods. Figures 1a, 1b, 1c, and 1d show the different IAACs the global offsets and the weighted rms values with respect to the weighted mean IGS TEC map, obtained with the new and with the old method (the plots of the old method end on 15 September). The plotted values were taken from the Table 1 of the daily short summary "igsg{ddd}0.{yy}s" (the values are denoted in Table 1 as "o" "S" in the old summary and as "o" "W" in the new summary).

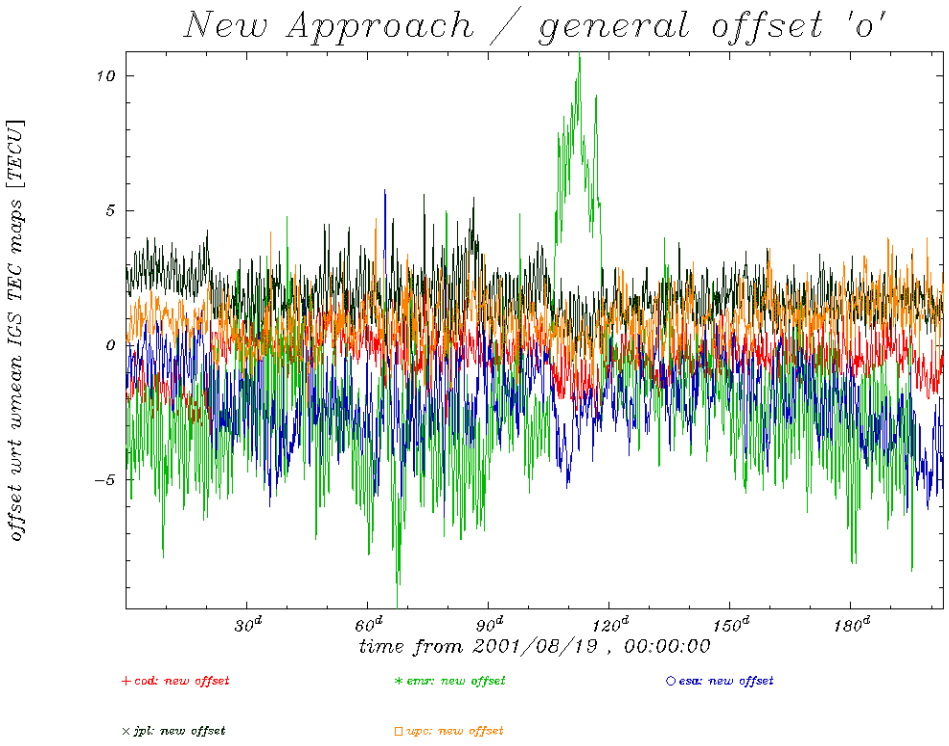

Figure 1a. IAACs global offsets and weighted rms values obtained with the new and with the old comparison/combination approach.

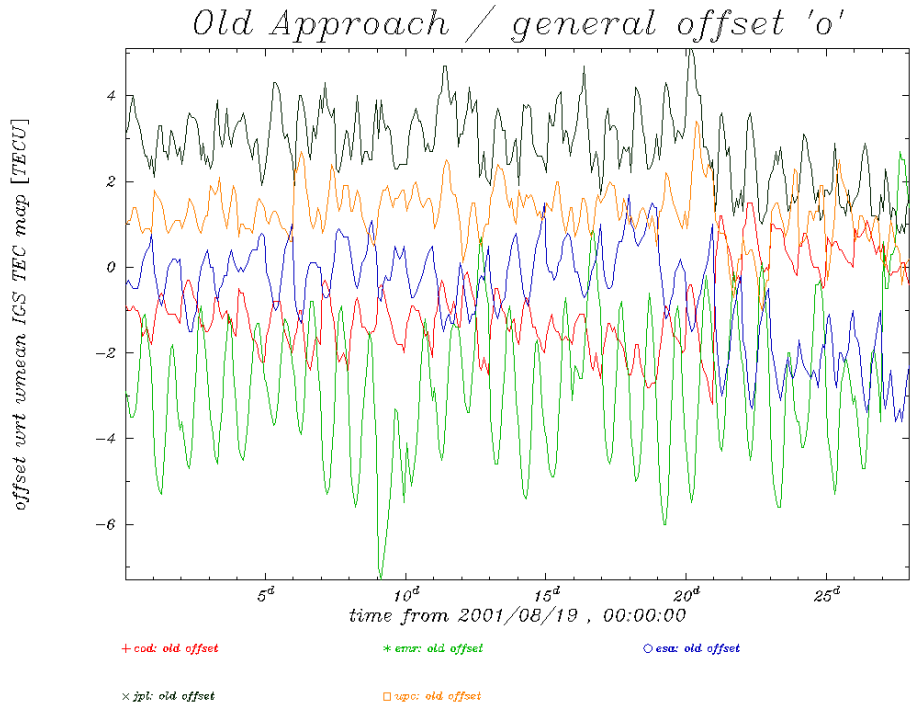

Figure 1b. IAACs global offsets and weighted rms values obtained with the new and with the old comparison/combination approach.

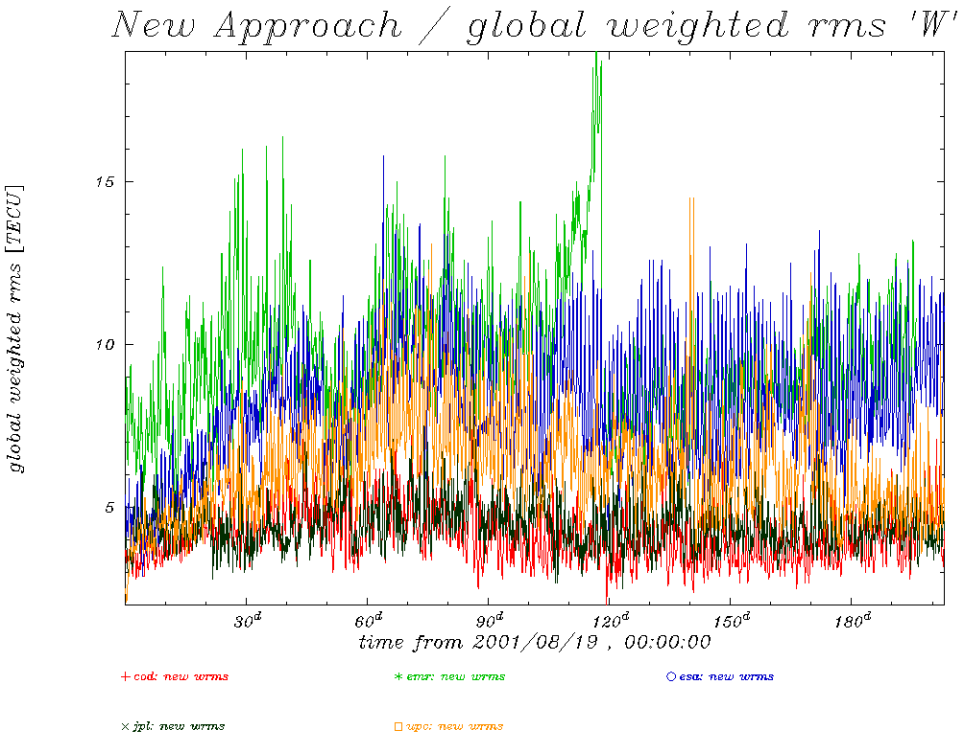

Figure 1c. IAACs global offsets and weighted rms values obtained with the new and with the old comparison/combination approach.

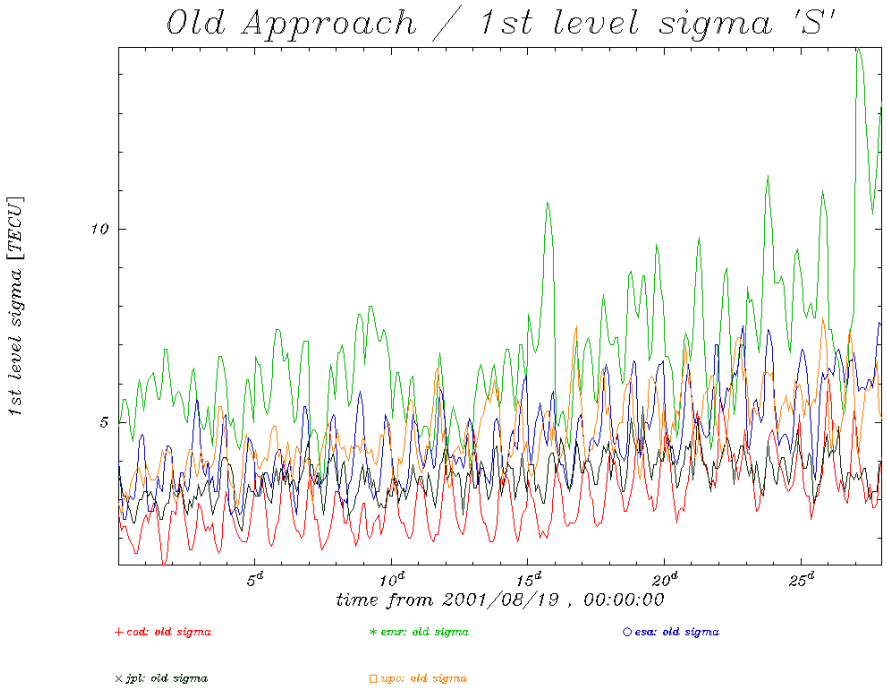

Figure 1d. IAACs global offsets and weighted rms values obtained with the new and with the old comparison/combination approach.

The curves in Figures 1a, 1b, 1c, and 1d seem to indicate that the new comparison/combination approach favours the higher quality TEC maps more than the old approach did.

On the northern hemisphere the deviations of the different IAAC TEC maps from the IGS "mean" are under normal conditions 5 TECU or less. On the southern hemisphere and especially at the equator the situation is more problematic, because of gaps in the station coverage at these latitudes. However, the deployment of new IGS stations in these areas has reduced these gaps since 1999, and the densification of the IGS ground sites net is ongoing.

Inherent in the application of the geographic-dependent weights, i.e. in assigning constant weight values to discrete geographic "areas", is a "chessboard-like" pattern of the weights when drawing them into a global map, and this pattern is then propagated into the combined RMS maps and sometimes also into the combined TEC maps (at the time when this Technical Report was written this problem had been solved by using global weights derived from the geographic-dependent ones from June 2002 on).

The day-by-day variations of the different IAAC GPS satellite DCBs series provided by most of the IAACs are quite constant, oscillating between 0.2 and 0.4 nanoseconds around their mean values.

TOPEX Validations

Since July 2001 JPL provides VTEC data derived from TOPEX altimeter observables to the working group to enable validations. At the IACC at ESOC a dedicated computer program has been set up to do that task; its runs are attached to the weekly comparisons.

Due to its orbital geometry TOPEX scans every day only a limited band of the ionosphere. Additionally, the TOPEX data may be biased by +2-5 TECU. These two aspects must be kept in mind when interpreting the validations with TOPEX VTEC data.

Principally these TOPEX validations work as follows: JPL provides per day a so-called TOPEX file containing VTEC values derived from TOPEX altimeter data in dependency of time, latitude and longitude. VTEC values are then interpolated in the different IAACs IONEX files for the same times/latitudes/longitudes, of which the corresponding TOPEX VTEC values are then subtracted. The VTEC-differences thus obtained are used to establish different kind of statistics, like mean daily offsets & related rms values for each IAAC. The TOPEX validation results are made available at ESOC's FTP account at the same place where also the comparison products can be found: ftp anonymous@nng.esoc.esa.de . They are always stored within the comparisons directory for a certain day in the subdirectory ~/TOPEX. For details see the TOPEX validation short - and long summary files located in these ~/TOPEX subdirectories.

Figures 2a, 2b, and 2c condense the basic statistics that were obtained from the TOPEX validations since 19 August 2001. The numbers plotted here were taken from the daily TOPEX validation long summaries "tpxobs.long.sum" and are denoted there as (see also Feltens, 2002a, Section 3.2, Figure 5):

mean	mean IAAC VTEC offset with respect to the TOPEX VTEC values, i.e. the mean value over n differences, d = tecval(IAAC) - TOPEXtec,
rms-diff	RMS of differences,
rms	RMS of residuals with respect to the mean.

In the meantime the following two statistics parameters were included too (Feltens, 2002a and Feltens 2002c):

sf/rms	estimate of the scale factor of the rms-values obtained from the TOPEX validation in relation to the corresponding IAAC rms values, should be close to one for IAAC = IGS, i.e. for the combined TEC maps,
wrms	a "mean" rms that might be an indicator for a TEC map's quality.

The TOPEX validations are done globally for all latitudes ("+90..-90") and separately also for medium and high northern latitudes ("+90..+30"), equatorial latitudes ("+30..-30") and medium and high southern latitudes ("-30..-90"). The daily TOPEX validation short summary "tpxobs.short.sum" contains only the global values. Beyond the IAACs TEC and the IGS TEC, also TEC computed with the GPS broadcast model ("gps") and TEC computed with CODE's Klobuchar-Style Ionosphere Model ("ckm") enter into the daily TOPEX validations. The latter two are provided by CODE. When inspecting the results from the different latitude bands one recognizes immediately that the best agreement of the distinct ionosphere models with the TOPEX data is achieved at medium and high northern latitudes, while the worst agreement is in the equatorial region. The agreement in the southern medium and high latitudes is more worse than in the northern ones, but as far as not as worse as in the equatorial latitude band.

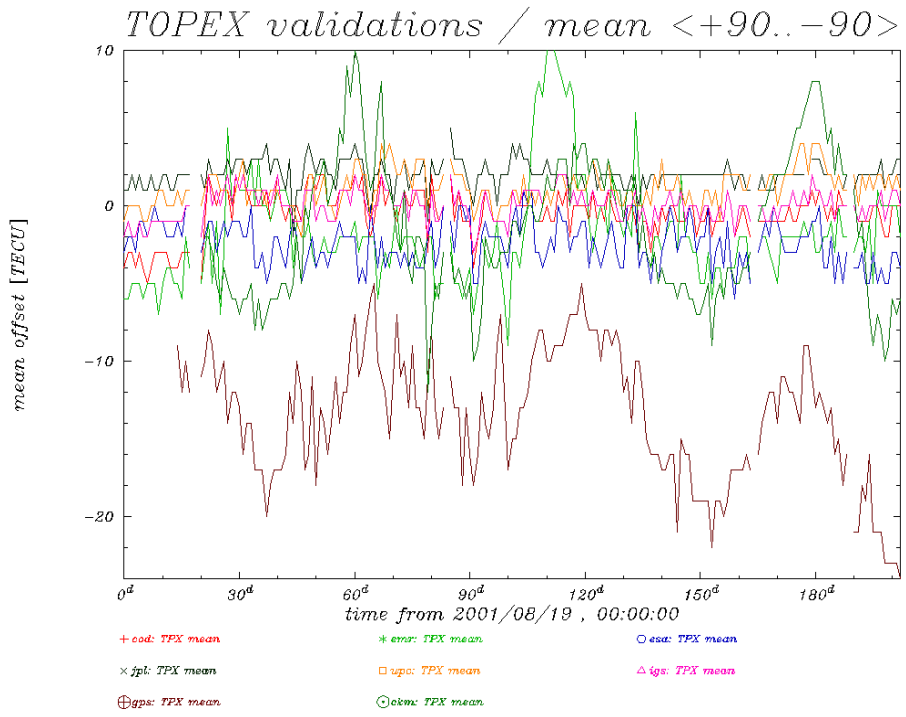

Figure 2a: The basic TOPEX validation statistics mean, rms-diff and rms.

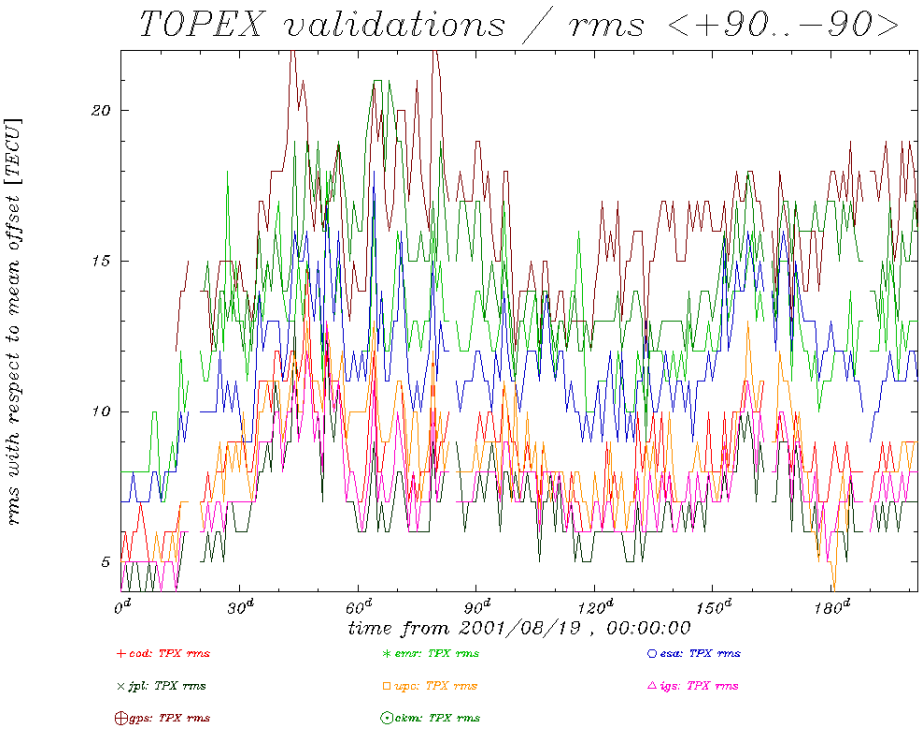

Figure 2b: The basic TOPEX validation statistics mean, rms-diff and rms.

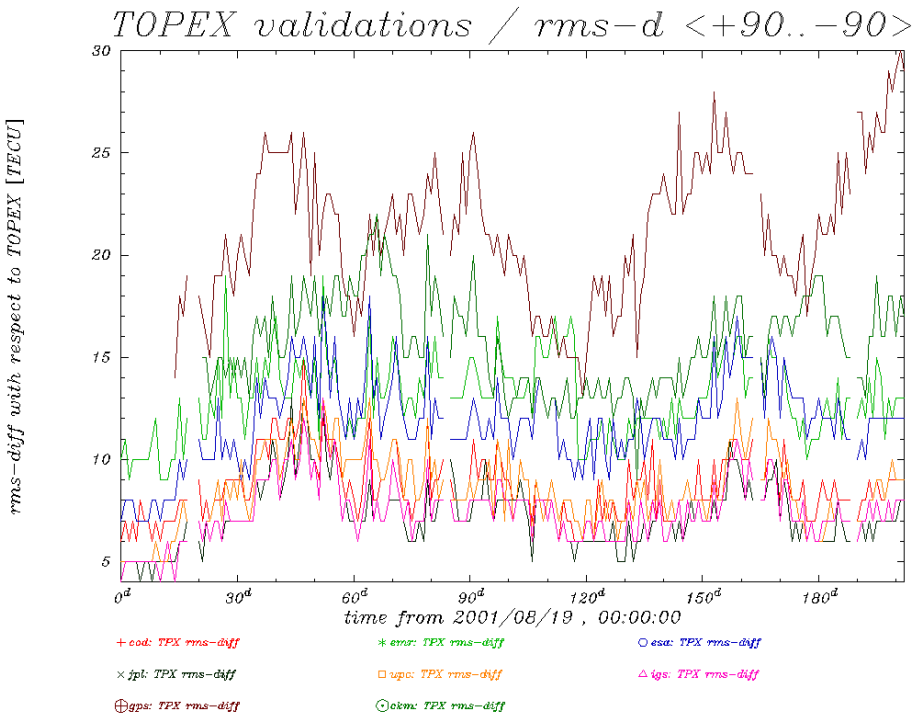

Figure 2c: The basic TOPEX validation statistics mean, rms-diff and rms.

The other thing that can be seen from Figures 2a, 2b, and 2c is that the IAACs TEC and the IGS TEC values, which are derived from GPS dual-frequency data, are considerably closer to the TOPEX TEC than the Klobuchar and especially the GPS broadcast model - and what is essential for the delivery of a combined IGS Ionosphere Product: The routine validations with TOPEX since July 2001 show an agreement of the "combined" IGS TEC maps with the TOPEX data on the same order as the best IAACs TEC maps.

Special Activities

During events which are of special interest for the ionosphere community and for ionospheric research, the Iono_WG organizes special high-rate tracking campaigns with the global IGS ground stations network. In the year 2001 the HIRAC/SolarMax campaign did run from 23 - 29 April: About 100 IGS sites, being located at the northern and southern polar regions and in the low latitudes including the crest regions at both sides of the geomagnetic equator, recorded over 7 days dual-frequency GPS data with 1- and 3-second sampling rates. This IGS/Iono_WG activity was coordinated with other ionospheric observation programs or measurement campaigns using ionosondes, EISCAT, high resolution magnetometers, etc. to obtain a comprehensive view of the geomagnetic and ionospheric state. The high rate GPS and GLONASS data are archived at the CDDIS and are open to research groups to study the ionosphere's behavior under solar maximum conditions (Feltens et al., 2001). The data are available at the CDDIS at ftp://cddisa.gsfc.nasa.gov/gps/01solarmax .

Figure 3 shows a global map with all IGS sites involved.

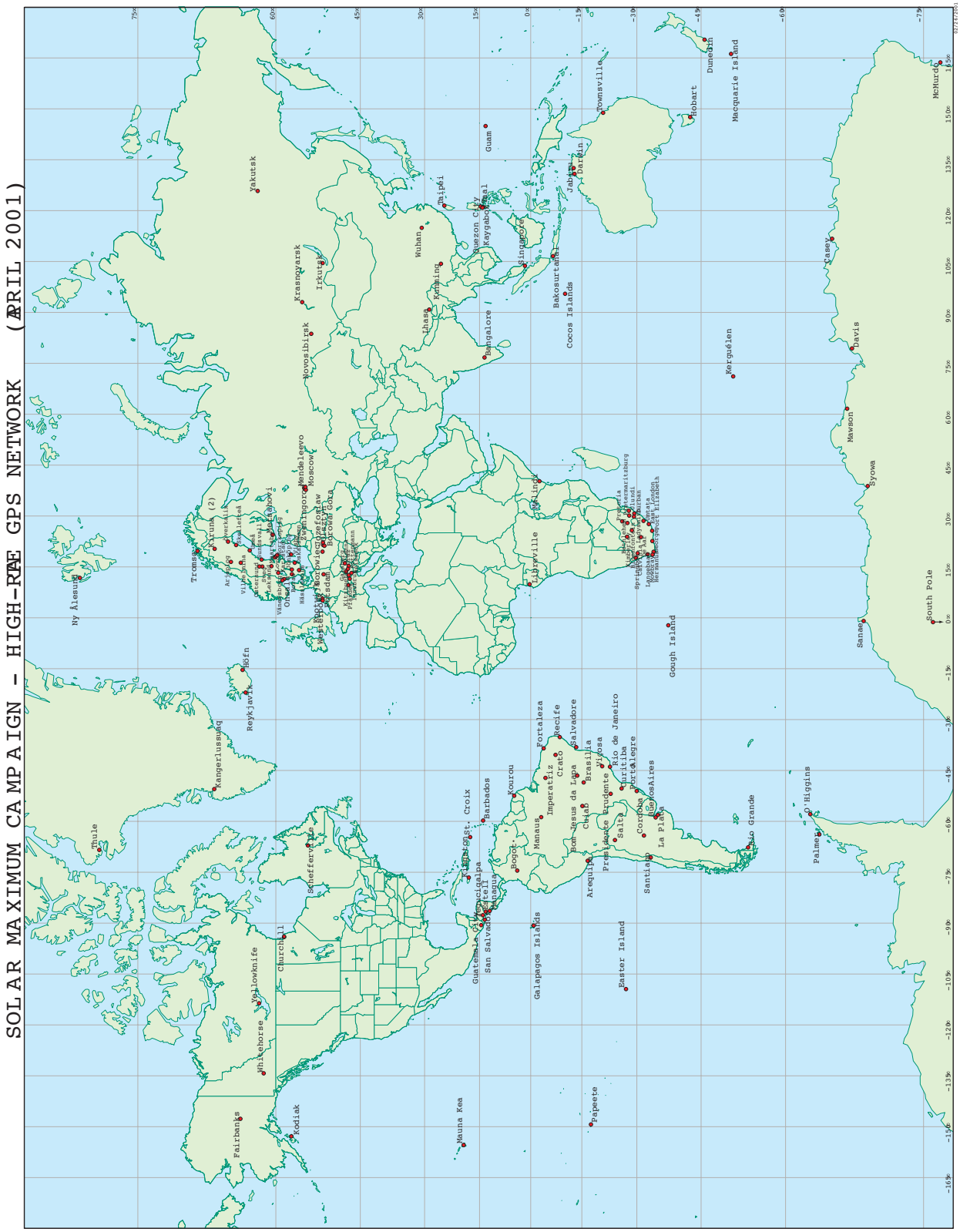

Figure 3: The HIRAC/SolarMax Campaign GPS/GLONASS Network
(courtesy C. Noll, CDDIS).

Future Tasks

At the IGS/IAACs Ionosphere Workshop at ESOC in Darmstadt, Germany, January 17-18, 2002 (Feltens, 2002b), and at the IGS Analysis Center Workshop at NRCan in Ottawa, Canada, April 8-11, 2002 (Feltens, 2002c), proposals and decisions were made on how to progress to bring the Iono_WG soon into a position to start, after the implementation last required upgrades in the comparison/combination program, with the routine delivery of a combined IGS ionosphere product. Some of these upgrades, like the global weights derived from the local weights and the inclusion of station DCBs, were done in the meantime (August 2001), others, like the change to even hour numbers, i.e. 0h, 2h, 4h, 6h, ... , 24h, for the combined IGS TEC maps and the improvement of the comparison/combination program output are currently under work. It is planned to complete these upgrades by the end of September 2002, so that the Iono_WG can then start with the routine delivery of an official combined IGS Ionosphere Product.

Beyond that major target, it is intended to implement, in addition to the TOPEX validations, also routine validations with ENVISAT and JASON satellite altimeter data during 2002.

The reduction of IGS ionosphere products delivery times up to a realization of a near-real-time service will then be another very important task and also the enhancement of the time resolution of ionosphere TEC maps to less than two hours. Corresponding pilot projects are planned.

Another aspect would the inclusion of other than GPS data, like Champ profiles, and considerations concerning the establishment of 3-d ionosphere models.

References

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